NanoWorld Journal

https://doi.org/10.17756/nwj.2023-s5-007

Research Article

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Microwave Absorption Property of Rice Husk and Graphene Oxide Composite Particle Board

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Received: October 11, 2023
Accepted: December 18, 2023
Published: December 21, 2023

Citation: Anilkumar R, Abhilash AP, Indhu KK, Aanandan CK. 2023. Microwave Absorption Property of Rice Husk and Graphene Oxide Composite Particle Board. *NanoWorld J* 9(S5): S36-S39.

Published by United Scientific Group

Abstract

Rice husk (RH) is an agricultural waste that can be used to improve microwave absorption by incorporating a nanoparticle such as graphene oxide (GO). A flat design of microwave absorption is simple and convenient for the protection of communication equipment from unwanted electromagnetic waves.

Keywords

Microwave absorber, Rice husk, Graphene oxide, Particle board, Free space measurement

Introduction

The need for innovative materials that can minimize or absorb electromagnetic radiation is growing due to the rapid expansion of communication equipment. Microwave absorbing materials are substances that lessen or absorb microwave radiation at microwave frequencies [1, 2]. Microwave absorbing materials were employed in order to minimize unwanted electromagnetic interference and safeguard commercial/industrial electronic equipment. A microwave absorber mostly depends on the material's inherent losses as well as its dielectric and magnetic properties [2].

RH, an agricultural waste of paddy (*Oryza sativa*), which is an agricultural waste, which is used as a foundation material for the preparation of microwave absorbing/shielding material. RH can be collected from farmers or rice mills. RH contains many organic matters such as lignin, cellulose, and hemicellulose. The other elements in the RH are SiO_2 (22.24%), carbon (35.77%), hydrogen (5.02%), and oxygen (36.59%). In India, the annual production of rice is around 104.86 million tons. RH is also used in many industrial applications. The powdered form of RH can be mixed with cement and will increase the strength of the concrete [3]. As Lee et al. mentioned in their article, the RH ash and RH are lossy materials that can be used to absorb microwave radiation [4].

Only a few studies were published in the literature that used a base layer to optimize agricultural absorbing materials. Nornikman et al. [5] and Iqbal et al. [6] prepared a pyramidal microwave absorber structure by utilizing the RH with insufficient attenuation of about 20 dB in the lower-frequency range of 2 to 4 GHz. Later on, they resolve the problem of lower attenuation. For instance, they changed the design of RH pyramid microwave absorber with 13 cm height and 2 cm base [5-8] and achieve the attenuation more than 45 dB.

The GO is compound of carbon, oxygen, and hydrogen in many flexible ratios, and it can be used as a catalyst, filler, and functionalized hybrid materials for energy conversion of different forms [9-11]. GO is comprised of a large number of functional groups including oxygen as well as an aromatic matrix.

To determine the physical and chemical properties of a material, it requires to evaluate the dielectric characteristics of that substance. For a material to be polarizable in an electric field, the dielectric constant value must be known [5]. The parameters to be evaluated are the dielectric constant, the loss tangent, and the reflection loss. There are both real and imaginary components to a material's permittivity. The real component of permittivity (ε′) quantifies the amount of energy a material may store in response to an applied electric field. The loss factor, or imaginary component of permittivity (ε″), quantifies the rate at which an external field causes energy to be dissipated or lost in a material. The loss tangent (tan δ) is a characteristic of a dielectric material that measures the rate at which electromagnetic energy is dissipated by the substance [5, 12]. The equation for loss tangent can be written as follows:

$$\tan\delta = \varepsilon''/\varepsilon'$$

To examine the absorption characteristics of a material, the electrical conductivity (δ) of the sample needs to be calculated as follows.

$$\sigma = 2\pi f \varepsilon_0 \varepsilon_r''$$

Where, $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m.

It is possible to describe the reflection loss or reflectivity 'R' of a material as the microwave absorption performance of the material. The formula for doing so is as follows.

$$R(dB) = 20\log_{10}(P_r/P_i)$$

Where, P_r denotes the power density of the reflected field and P_i denotes the power density of the incident field [5].

Experimentation

Materials

Samples of RH were collected from a rice mill. RH's primary components and characteristics were described in table 1 [10, 11]. GO powder, H_2O_2 (Hydrogen peroxide), epoxy resin, and hardener was purchased from Kochi (Kerala, India).

RH particle board preparation

First, the raw RH is treated with H_2O_2 for cleaning purposes. The fabricated RH particle board with nanoparticle GO is shown in figure 1a to figure 1d with the dimension of 25 cm width, 25 cm long, and 3 mm thickness. The density of RH [4] is 1.2 g/cm^2. The procedure of particle board fabrication is illustrated in figure 2. To fabricate the RH particle board (76 g total mass), first mix 38 g epoxy resin ($C_{21}H_{25}ClO_5$), 28.5 g powdered RH, 9.5 g GO powder, and a hardening agent. For the purpose of joining the combined material particles, the hardening agent (Triethylenetetramine ($C_6H_{18}N_4$)) is utilized as a glue.

Next, the combined mixture is poured into a mold with a square form as the above dimension. The method of molding involves shaping malleable raw material using a hard model or frame. Using a hydraulic press machine, this mold is used to create particle board that has a square appearance. The hydraulic press machine is used to compress materials into standard objects like particle board or pre-formed shapes.

Table 1: Elements in the RH.

Element	% Element
Carbon	41.44
Hydrogen	4.94
Oxygen	37.32
Nitrogen	1.1
Silicon	14.66
Potassium	0.59
Sodium	0.035

Figure 1: (a) Raw RH, **(b)** RH powder after treated with H_2O_2, **(c)** GO, and **(d)** Fabricated RH and GO particle board.

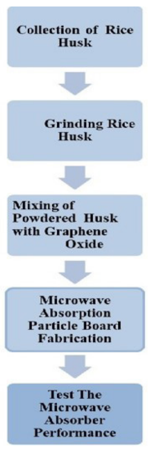
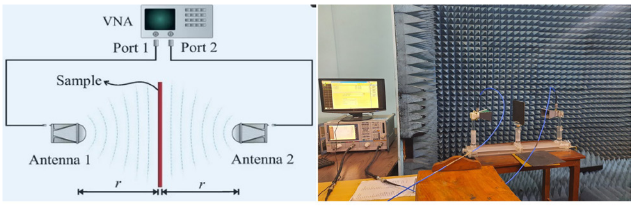


Figure 2: Making RH particle board.

Sample measurement techniques

An ultra-wide band pyramidal horn antenna was used for the measurement. The objective of the work is to systematically characterize the performance of the reflectivity of the material to determine the microwave absorbing characteristics. The result of the measurement will illustrate functions of the microwave absorber that has been fabricated for the absorbing characteristics. Two elements will be considered in the measuring process: first the electromagnetic characteristics of the microwave absorber and second is the reflectivity performance of that material. Dielectric properties are measured in order to describe the various materials utilized and to specify the physical and chemical characteristics associated to energy storage and loss [13, 14]. For the dielectric constant measurements, co-axial probe technique was used. The dielectric constant (ε′) of the RH material and loss tangent is calculated as ε′ = 2.99295, and tan δ = 0.20614.

For the measurement of reflection loss, a free space measurement (FSM) technique is employed. Figure 3 and figure 4 show the FSM set up in the laboratory.



(a) (b)

Figure 3: (a) A diagrammatic representation of the FSM and **(b)** FSM set up for microwave absorption of RH particle board.

Table 2: Performance of reflection coefficient of RH particle board.

Frequency range (GHz)	Reflection coefficient (dB)	Absorption (%)
2 - 4	-26.471	94.13
4 - 6	-25.814	93.17
6 - 8	-17.542	91.58
8 - 10	-25.935	92.69
10 - 12	-27.235	96.41
12 - 18	-18.251	91.72

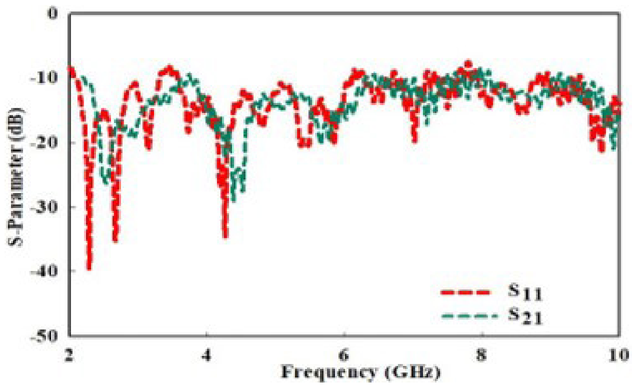


Figure 4: Scattering parameters S_{11} and S_{21}.

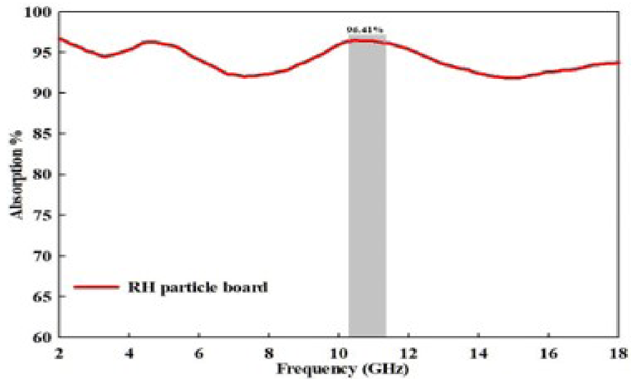


Figure 5: Microwave absorption plot at 2 to 18 GHz frequency.

In FSM, two antennas are connected to a vector network analyzer. In this technique (size of FSM apparatus depends on the measuring frequency) the material under test is to be use large and flat. In FSM, through-Reflect-Line, through-Reflect-Match, and Line-Reflect-Line modalities can be employed for the material parameter measurements. The Line-Reflect-Line produces heights accuracy. The transmission and reflection can be characterized by the S-Parameters: S_{11}, S_{12}, or S_{21}. The S-Parameters of the sample are used for extracting the electromagnetic properties. The test frequencies were used 2 - 18 GHz frequency.

The RH particle board is positioned between two horn antennas in non-contact mode. The ultra-wide band microwave signal is transmitted from port 1 to port 2 through horn antennas. In the measurement, the S-Parameter S_{11} at port 1 is the reflected signal and S_{21} for port 2 is the transmitted signal. Let 'r' be the spacing between the sample and horn antenna. When 'r' is too large, the received signal is weak and excessive noise is produced by the receiving horn. If 'r' is too small, the signal transmitted to planar surface and the sample is not in plane wave form and occurs very less precise result.

$$r = 2D^2/\lambda$$

Where, 'D' is aperture of horn antenna.

Results and Discussion

Figure 1d is an illustration of a particle board made in the laboratory from RH. The manufactured material has a dielectric constant (ε′) of 2.4229, according to the calculations. The reflection loss performance of the RH particle board microwave absorber is given in table 2. From figure 4, it shows that it gained up to -28 dB of reflection loss performance in the range 2 - 10 GHz. At low frequency and beyond 10 GHz frequency the reflection loss performance is not good enough. The absorption of the microwave can be calculated as:

$$A = 1 - (S_{11})^2 - (S_{21})^2$$

The maximum absorption of the microwave by the particle board was achieved 96.41 at the frequency of 11.08 GHz and it's all parameters are plotted in figure 5.

Conclusion

In this particle board, the material study proves the agro-based byproducts like RH with GO have a capability to absorb microwave signal at frequency range 2 - 10 GHz. It is easy and low cost to design and fabricate. It will help to save nature from environmental hazards.

Acknowledgments

The authors acknowledge the support from the Technical Education Department, Kerala and CSIR Emeritus Scientist scheme.

Conflict of Interest

None.

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